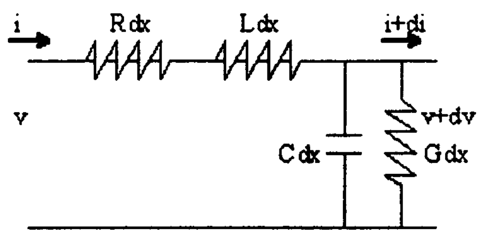
next up previous
Next: Summary of properties for the coaxial line

II. The model for studying the coaxial cable transmission line

The significant circuit parameters for a transmission line are shown below



R, L are the series resistance and inductance per length. C, G are the shunt capacitance and conductance per length.

We can get the fundamental equations of transmission line theory,

$$-\frac{\partial v}{\partial z} = Ri + L\frac{\partial i}{\partial t} \quad ; \quad -\frac{\partial i}{\partial z} = Gv + C\frac{\partial v}{\partial t}$$

Such kind of linear differential equations can be solved by means of Laplace transforms.

First, do the Laplace transform on both sides of each differential equation,

$$-\frac{\partial \tilde{V}}{\partial z} = R\tilde{I} + Ls\tilde{I} - Li_{t=0} \quad ; \quad -\frac{\partial \tilde{I}}{\partial z} = G\tilde{V} + Cs\tilde{V} - Cv_{t=0}$$

Second, solve these two coupled equations, do the second derivative with respect to z(the propagation direction) and substitute original equations into them, we get

$$\frac{\partial^2 \tilde{V}}{\partial z^2} = (R + Ls)(G + Cs)\tilde{V} \quad ; \quad \frac{\partial^2 \tilde{I}}{\partial z^2} = (R + Ls)(G + Cs)\tilde{I}$$

the solutions are

II. The model for studying the coaxial cable transmission line

$$\tilde{V} = A_1 e^{-z\sqrt{(R+Ls)(G+Cs)}} + B_1 e^{z\sqrt{(R+Ls)(G+Cs)}} \quad ; \qquad \tilde{I} = A_2 e^{-z\sqrt{(R+Ls)(G+Cs)}} + B_2 e^{z\sqrt{(R+Ls)(G+Cs)}}$$

we can define $\gamma = \sqrt{(R+Ls)(G+Cs)}$, which is just so called the propagation constant of the line.

Considering the practical physical meaning,

$$B_1 = 0 \quad ; \quad A_1 = \tilde{V}(z=0,s) = \mathcal{L}(v(z=0,t)) = \mathcal{L}(v_0(t)) = \tilde{V}_0(s)$$
$$B_2 = 0 \quad ; \quad A_2 = \tilde{I}(z=0,s) = \mathcal{L}(i(z=0,t)) = \mathcal{L}(i_0(t)) = \tilde{I}_0(s)$$

where $\tilde{V}_0(s)$ $\tilde{I}_0(s)$ are just the Laplace transform of the initial signal at the origin. The transfer function is defined as $H(j\omega) = H(s) = e^{-\gamma} = e^{-z\sqrt{(R+Ls)(G+Cs)}}$

From the relation of $\tilde{V}_0(s)$and $\tilde{I}_0(s)$, we have $\frac{\tilde{V}}{\tilde{I}} = \frac{\tilde{V}_0}{\tilde{I}_0} = \sqrt{\frac{R+Ls}{G+Cs}} = Z_0$

this quantity is called the surge impedance of the transmission (or the characteristic impedance) of the transmission line.

Finally, find the inverse transform

$$v(z,t) = \mathcal{L}^{-1}(\tilde{V}_0(s)e^{-z\sqrt{(R+Ls)(G+Cs)}}) \quad ; \quad i(z,t) = \mathcal{L}^{-1}(\tilde{I}_0(s)e^{-z\sqrt{(R+Ls)(G+Cs)}})$$

we obtain the ware form function in our familiar space-time frame.

In general case, signals propagate in a transmission linewith distortion due to the limitation of bandwidth and the certain change of the spectrum the signals by the transmission line. Although the distortionless casemaybe of specific interest, here I just concentrate on the more common phenomenon--distortion., which is taking place on most signal transmission.

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[x] next [x] up [x] previous

Next: Summary of properties for the coaxial line

Derek Yong Qin (e-mail: yqin@wpi.edu)

Last modified: Feb.21, 97

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Aston University

Department of Electronic Engineering and Applied Physics

HSPICE User Guide: Transmission Lines Supplement

INTRODUCTION

This document should be read in conjunction with the ' HSPICE User Guide'. It covers additional information required to model and simulate transmission lines with HSPICE.

A transmission line is a device intended to deliver an output signal at a distance from the point of signal input. Transmission lines include power cables, telephone lines, and waveguides. Less obviously perhaps, printed circuit boards, multi-chip modules and even integrated circuit packages have to be considered as transmission lines when operating frequencies are high.

The extra effects which are introduced by transmission line models are: time delay, phase shift, power loss, distortion and reduction of bandwidth.

HSPICE provides facilities for modelling lossless (ideal) and lossy transmission lines.

It also provides facilities to model numerous different physical layouts of the conductors forming the transmission lines. In this document only coaxial cables and twin-lead cables are described. Full details are in the Meta-Software HSPICE manual. See Mr. Wilton if you wish to consult that manual.

This document is also available in PostScript format on the Aston University WWW server. (URL `http://www.eeap.aston.ac.uk/eeap/documents/user-guides.html`).

HSPICE TRANSMISSION LINE ELEMENTS

There are two transmission line elements. The T element is used for ideal transmission lines and the U element for lossy transmission lines. In addition the U model may be used to combine ideal and lossy elements. However, it is often convenient (and more consistent) to use the U model with the relevant parameters even for ideal lines.

The ideal line is modelled as a voltage source and a resistor. The lossy line is modelled as a multiple lumped filter section.

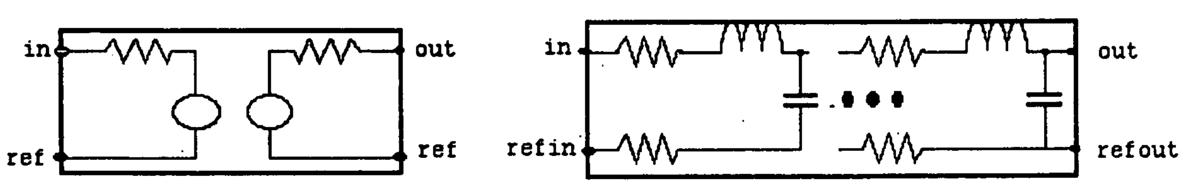


Fig 1. Ideal and lossy transmission line models

LOSSLESS TRANSMISSION LINE (T ELEMENT)

Syntax

```
Txxx in refin out refout <mname> z0=val td=val L=val
```

`in` Signal node (in side)

`refin` Ground reference for input.

`out` Signal node (out side)

`refout` Ground reference for output.

`mname` U model reference name

`z0` Characteristic impedance

`td` Transmission delay (secs/m)

`L` Physical length of the transmission line in metres. The default value is 1m.

LOSSY TRANSMISSION LINE (U ELEMENT)

Syntax

For 1 wire and ground plane

```
Uxxx in refin out refout mname L=val
```

For 2 wires without ground plane (unshielded twin)

```
Uxxx in1 in2 out1 out2 mname L=val
```

For 2 wires and ground plane

```
Uxxx in1 in2 refin out1 out2 refout mname L=val
```

`in, in1, in2` Signal node(s)(in side)

`refin` Ground reference for input.

`out,out1,out2` Signal node(s) (out side)

`refout` Ground reference for output.

`mname` U model reference name

`L` Physical length of the transmission line in metres. The default value is 1m.

TRANSMISSION LINE MODEL (U MODEL)

The U model is intended for specifying the extra parameters for lossy lines but it is convenient to use it also to specify the parameters required for lossless lines.

The syntax is:

```
.MODEL mname U LEVEL=3 PLEV=x ELEV=x <DLEV=x>

+ <Pname=val> ...
```

`mname` Model name.

`PLEV` Physical level. Used to distinguish between planar conductors (PLEV=1), Coaxial conductors (PLEV=2),Twin and twisted pair conductors (PLEV=3)

`ELEV` Electrical level. Used to distinguish modelling via geometry such as thickness, width, dielectric (ELEV=1), pre-calculated equivalent resistance, capacitance and inductance (ELEV=2), measured impedance and delay (ELEV=3).

`DLEV` Device level. A further level of refinement for different conductor/dielectric configurations.

In this document only geometric and measured parameter modelling are considered.

GEOMETRIC MODELLING (ELEV=1)

Coaxial cable

Geometric coaxial cable modelling is selected with U model parameters PLEV=2, ELEV=1. the DLEV parameter is not required.

```
.MODEL mname U LEVEL=3 PLEV=2 ELEV=1 <Pname=val> ...
```

The physical geometry parameters for coaxial cable are shown in Fig. 2 and described in Table 1.

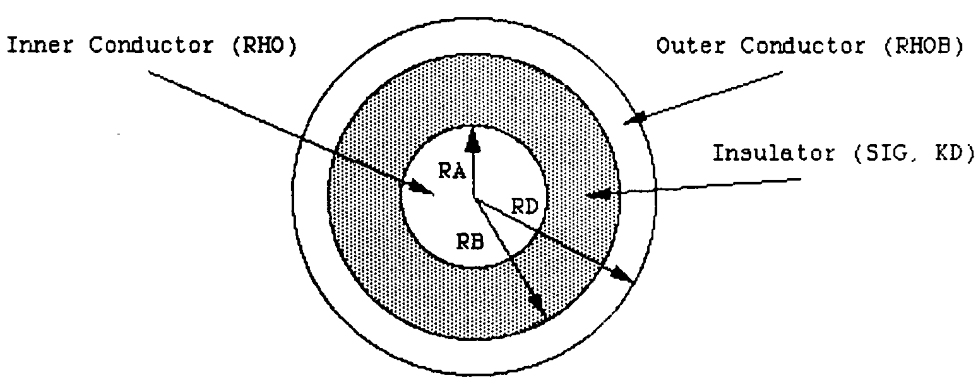


Fig. 2. Coaxial Cable geometry

Name	Unit	Default	Description
RA	m	required	Outer radius of inner conductor
RB	m	required	Inner radius of outer conductor (shield)
RD	m	RA+RB	Outer radius of outer conductor (shield)

HGP	m	1.5.RD	Radius to circuit ground point
RHO	[[Omega]]m	17E-9	Resistivity of conductor material (default=Copper)
RHOB	[[Omega]]m	RHO	Resistivity of shield material
SIG	[[Omega]]-1m-1	0.0	Conductivity of dielectric
KD		4.0	Relative dielectric constant

Table 1. Geometric Coaxial cable parameters

Twinlead cable

Geometric twinlead cable modelling is selected with U model parameters PLEV=3, ELEV=1. Differences caused by the presence of a shield are indicated by a third parameter DLEV. The different geometric parameters are shown in Fig 3a (sea of dielectric), Fig. 3b (insulating spacer) and Fig. 3c (shielded). The parameters are described in Table 2.

Name	Unit	Default	Description
DLEV		0	Device Level.
RA1	m	required	Outer radius of conductor 1
RA2	m	RA1	Outer radius of conductor 2
D12	m	required	Distance between conductor centres
RHO	[[Omega]]m	17E-9	Resistivity of conductor material (default=Copper)
KD		4.0	Relative dielectric constant
SIG	[[Omega]]-1m-1	0.0	Conductivity of dielectric
HGP	m	1.5.D12	Radius to circuit ground point
RHOB	[[Omega]]m	RHO	Resistivity of shield (if present)
OD1	m	required	Maximum outer dimension of shield (if present)
OD2	m	OD1	Minimum outer dimension of shield (if present)

Table. 2. TwinLead cable parameters

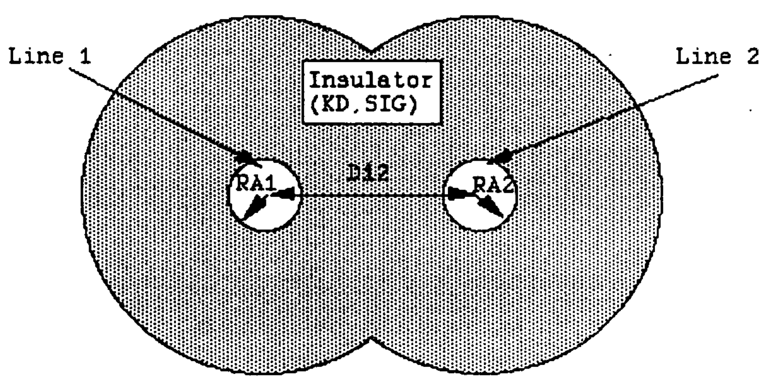


Fig. 3a. TwinLead cable (sea of dielectric) geometry

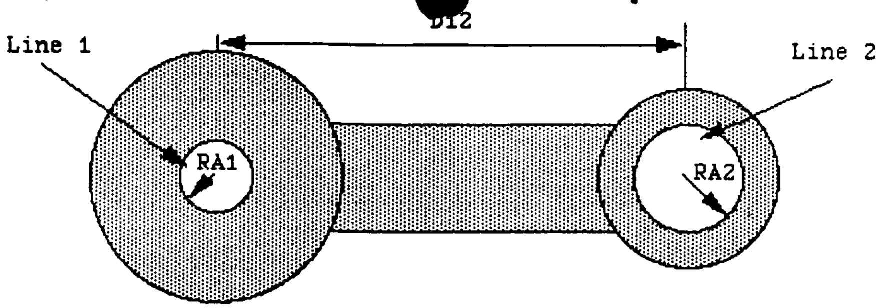


Fig. 3b. TwinLead cable (insulating spacer) geometry

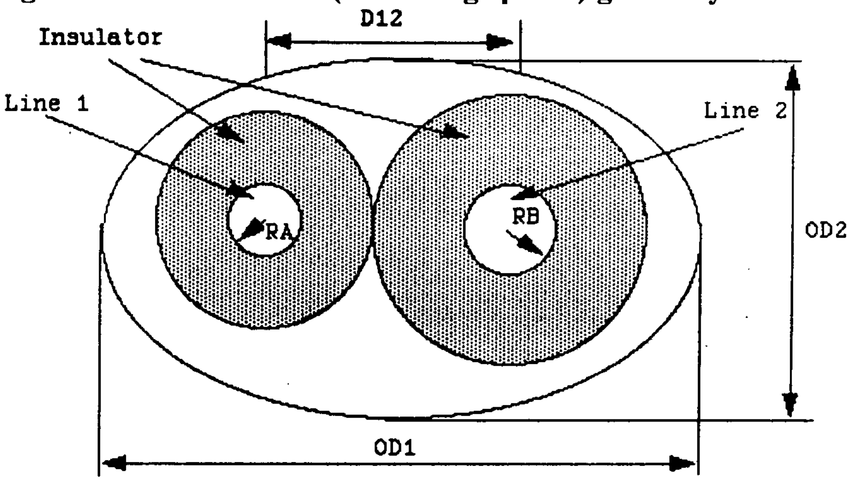


Fig. 3c. TwinLead cable (with shield) geometry

PRE-COMPUTED ELEMENT MODELLING (ELEV=2)

Not covered in this document.

MEASURED ELEMENT MODELLING (ELEV=3)

When measured parameters are given. HSPICE calculates the resistance. capacitance and inductance parameters using TEM transmission line theory. If some parameters are redundant HSPICE guesses which are most likely to be accurate and discards the others.

This modelling method is most useful for standard cable types where the parameters can be extracted from tables.

Name	Unit	Default	Description
ZK	[[Omega]]	calculated	Characteristic impedance
VREL		calculated	Relative velocity of propagation
DELAY	sm-1	calculated	Delay/length
CAPL	Fm-1	1.0	Capacitance/length
AT1	m-1	1.0	Attenuation factor/length

Table 3. Measured parameters

The measured parameters for some standard cables are given below.

Coaxial cable type RG58 (Thin Ethernet)

```
.model rg58c u level=3 plev=2 elev=3 zk=50 capl=100.7p

+ vrel=0.66 frl=100meg atl=0.173db
```

Twisted pair (Shielded)

```
.model tw/sh u level=3 plev=3 elev=3 zk=300 capl=25.5p

+ vrel=.698 frl=57meg atl=0.0566db
```

Twisted Pair (Unshielded)

```
.model tw/un u level=3 plev=3 elev=3 zk=300 capl=17.3p

+ vrel=.733 frl=100meg atl=0.0458db
```

OTHER TRANSMISSION LINE PARAMETERS

There are a few U model parameters which may be used irrespective of the type of transmission line. These are used to control the simulation algorithms.

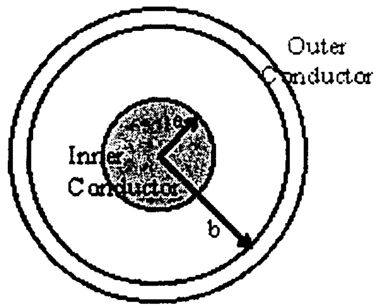
`WLUMP=val` Number of lumps per wavelength for error control. The default value is 20.

`MAXL=val` Maximum number of lumps per element. The default value is 20.

Return to EEAP Department Home Page

III. Summary of properties for the coaxial line

Cross section of coaxial cable,



Basic formula[1]:

skin depth $\delta = \sqrt{\dfrac{2}{2\pi f \mu \sigma}}$

the series resistance R(the skin effect impedance Rs) per length

$$R = \frac{1}{2\pi}\left(\frac{1}{a} + \frac{1}{b}\right) R_s \quad \Omega/m; \qquad R_s = \sqrt{j2\pi f \frac{\mu}{\sigma}} \quad \Omega/m^2$$

series inductance per length $L = \dfrac{\mu}{2\pi} \ln\left(\dfrac{b}{a}\right) \quad H/m$

the shunt capacitance per length $C = \dfrac{2\pi \varepsilon}{\ln\left(\dfrac{b}{a}\right)} \quad F/m$

the shunt conductance per length $G = \dfrac{2\pi \sigma}{\ln\left(\dfrac{b}{a}\right)} \quad 1/(\Omega \cdot m)$

next up previous

Next: Properties of coaxial cable RG-58 A/U

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Academic Press Dictionary of Science and Technology

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spreader a device that spreads; specific uses include: *Civil Engineering*. **1.** any appliance that distributes water uniformly in or from a channel.any appliance that distributes water uniformly in or from a channel. **2.** a machine fitted with wide plates for spreading soil, subsoil, or rock excavated from a pond, drainage ditch, or other cut.a machine fitted with wide plates for spreading soil, subsoil, or rock excavated from a pond, drainage ditch, or other cut. *Mining Engineering*. **1.** a timber placed horizontally below the cap of a set to stiffen the legs and support the brattice when two air courses are in the same gangway.a timber placed horizontally below the cap of a set to stiffen the legs and support the brattice when two air courses are in the same gangway. **2.** a piece of timber set across a shaft for temporary wall support.a piece of timber set across a shaft for temporary wall support. *Electricity*. an insulator used to separate the wires of an [redacted]. *Mechanical Engineering*. a tool used in sharpening machine drill bits.

Previous Words
spray torch spray tower spray transfer spray-up spread

Next Words
spreader beam spreader stoker spread footing spreading activation, spreading coefficient

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Patent Specification No. 466,418
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